A Project Report on

DESIGN, OPTIMIZATION AND ECONOMIC FEASIBILITY OF ABSORPTION REFRIGERATION SYSTEM USING (LITHIUM BROMIDE + WATER) AS WORKING PAIR

In partial fulfilment of the requirements for the degree in

Bachelor of Technology in Chemical Engineering

Submitted by

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CERTIFICATE

This is to certify that the thesis entitled, "**DESIGN, OPTIMIZATION AND ECONOMIC FEASIBILITY OF ABSORPTION REFRIGERATION SYSTEM USING (LITHIUM BROMIDE + WATER) AS WORKING PAIR"**, submitted by **Mr. Soumya Ranjan Mohanty, Roll no. 111CH0102**, in partial fulfilment of the requirements for the award of degree of Bachelor of Technology in Chemical Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the report has not been submitted to any other University / Institute for the award of any Degree or Diploma.

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ABSTRACT

The global warming and energy crisis have become two most important environmental problems of this twenty-first century. To overcome these problems, scientists have worked on inventing different devices to lessen this impact. Vapour absorption refrigeration cycles are the products of this ideology. Absorption refrigeration cycle generally works on the solar energy, but it can also verywell work on waste heat sources i.e. heat generated from data centres, different industries and from large hotels. If this waste heat is being used then not only energy crisis will decrease but also environment pollution will reduce to a greater extent. Though industrial point of view, absorption refrigeration cycle is an old concept, but from academic point, there is still needed a lot of works to be carried out to visualise different aspects like its performance, heat and mass coefficients and fluxes. This project work is based on the simulation, optimum designing as well as finding out the economic feasibility. LiBr+water is taken as the working pair to do the simulation, analysis and design of an absorption refrigeration cycle. At the end of this project work, economic feasibility has also been found out. When compared with a vapour compression refrigeration cycle, it can be visualized that the vapour absorption refrigeration system has an annual profit of around Rs. 7500/- which shows the economical viability of this refrigeration system.

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NOMENCLATURE

Symbol	*Name*
COP	Coefficient of performance
LiBr	Lithium bromide
Rs	Rupees
T_a	Temperature of absorber(˚C)
T_c	Temperature of condenser(˚C)
T_e	Temperature of evaporator(C)
T_g	Temperature of generator(˚C)
T	Temperature(˚C)
P	Pressure(mmHg)
X	Concentration fraction
H	Enthalpy(KJ/Kg)
M	Mass flow rate of refrigerant(Kg/s)
M_s	Mass flow rate of strong solution(Kg/s)
M_w	Mass flow rate of weak solution(Kg/s)
m_1	Mass flow rate at stream 1(Kg/s)
h_1	enthalpy at stream 1(KJ/Kg)
Wp	Pump work(W)
KW	Kilo watt
Q_a	Heat duty of absorber(KW)
Q_c	Heat duty of condenser(KW)
Q_e	Heat duty of evaporator(KW)
Q_g	Heat duty of generator(KW)
ABSOR	Absorber
CONDENS	Condenser
EVAPO	Evaporator
B10	Waste heat supplying block
KWh	Kilo watt hour
Yr	Year
Hr	Hour

DESIGN, OPTIMIZATION AND ECONOMIC FEASIBILITY OF ABSORPTION REFRIGERATION SYSTEM USING (LITHIUM BROMIDE + WATER) AS WORKING PAIR

CHAPTER – 1

INTRODUCTION

1.1 INTRODUCTION :-

Today's world is facing two most important environmental problems. They are the energy crisis and the green house effect. Scientists are working on how to eradicate these problems. Most of the today's innovations are based on this fact. Lithium-Bromide and water driven absorption refrigeration cycle is a burning example of this concept, which not only helps in minimizing the fossil fuel usage, hence the reduced CO_2 gas emission but also utilizes the low-grade heat from various industries and data centres.

The vapour absorption refrigeration cycle or the absorption refrigerator is a closed loop cycle that uses low grade heat (waste heat) to provide cooling or refrigeration . It is different from the conventionally used vapour compression refrigerator in the sense that it works on chemical energy rather than electrical energy. The absorption refrigerator uses a chemical substance as the absorbent which absorbs the refrigerant in the absorber and the waste heat is being used to recover the refrigerant free absorbent and enable it to be reused. (Ammonia + water) and (Lithium-bromide + water) are the two commercially used working pairs for this kind of refrigerators with their operability limitations.

In this project, simulation analysis and design of an absorption refrigeration system using the LiBr + water working pair has been carried out, where water works as refrigerant and LiBr works as absorbent. The efficiency of this refrigerator is around 1.0 and from the simulation work, the optimized cycle's coefficient of performance (COP) has been found out to be 1.0065. This work also attempts to find out the economic evaluation of this system in comparison to vapour compression refrigeration cycle. The project work revels that installing an absorption refrigeration system for low grade heat recovery is beneficial than the vapour compression refrigeration cycle. This thorough investigation of this commercially used absorption refrigeration system may pave the way to carry out similar exercise using some novel working pairs to be used in near future.

1.2 LITERATURE REVIEW :-

In the early twentieth century, vapour absorption refrigerator were used extensively taking ammonia and water as working pairs, but due to the easy availability of electricity and developments of vapour compression refrigeration cycle, decreased the use of absorption refrigerators. The outcome of less efficiency is another factor for its minimal use. But still now-a-days, these refrigerators may find their usage depending on the availability of low grade heat, solar and geothermal energy.[1]

A.Yokozeki[1] has first done the modelling of vapour absorption refrigeration using equation of states. He has considered various refrigerant-absorbent pairs, mainly two conventionally available pairs i.e LiBr+water and ammonia+water. Though the development of this kind of absorption refrigeration system have been carried out since 1932, but this kind of complete thermodynamic study and computer based modelling has made other scientists and researchers to study the different aspects and behaviours of these kinds of working pairs. He has done large number of experiments to find out the cycle performance of these kinds of refrigerators so that the temperature, pressure, concentration and enthalpy data have been easily found out.

In recent developments of thermal engineering, refrigeration technology plays an important role in their industrial applications. But as far as the COP is concerned, it has always posed challenges to the researchers in enhancing the efficiencies of these systems. The most popular refrigeration and air conditioning system at present is the conventional vapour compression systems. These systems are popular because of their inexpensiveness and reliability. However these systems require high grade energy i.e. mechanical or electrical energy for their operations necessitating depletion of fossil fuel, hence CO_2 emission. Besides, it has been found out that the conventional refrigerants used in these refrigerators are harmful towards environments and cause ozone layer depletion. Hence the logical alternative is obviously the vapour absorption refrigerator system which mainly uses low grade heat energy for the operations and acts as a saviour of thermal pollution. The most interesting thing of these refrigerators is that, they are environment friendly which is the need of this hour.[2] S.Kaushik has done the analytical work on absorption refrigeration systems to find out the COP values [2]. He has done most of his works on LiBr+water system and found out all the state point enthalpy values experimentally

1.3 LIBR + WATER BASED ABSORPTION REFRIGERATION SYSTEM

The use of LiBr + Water for absorption refrigeration system started around 1930s. The outstanding features of LiBr+water system is the non-volatility of the absorbent i.e. LiBr. This eliminates the use of rectifier as used in Ammonia+ water based absorption refrigeration system. Another advantage is the high heat of vaporization of refrigerant i.e. water. But the use of water as refrigerant also restricts the use in low temperature applications. The COP of these kinds of refrigeration system is higher than the ammonia + water based refrigeration system. The thermodynamic analysis of the system involves finding important parameters like enthalpy, mass flow rates, coefficient of performance (COP), heat and mass transfer and crystallization in LiBr + Water system[2]. The thermodynamic analysis is carried out with the following assumptions:-

1. Steady state and steady flow
2. No pressure drops due to friction
3. Pure refrigerant comes out from the generator through the refrigerator circuit in form of vapour.

Refrigerant absorbent systems should possess some desirable properties for vapour absorption cycle. These are as follows-

- The refrigerant should be more volatile than the absorbent in other words the boiling point of refrigerant should me less than that of absorbent.
- There should be large difference in their boiling points so that it will be easier to separate them in the generator. This ensures that pure refrigerant flows through the refrigerant circuit (condenser, expansion valve and evaporator)
- The refrigerant should exhibit high solubility with solution in the absorber.
- The absorbent should have strong affinity for the refrigerant, this will minimize the amount of refrigerant to be circulated.
- Operation pressure should be low so that the pipe walls need not to be strong.
- It should not undergo crystallization otherwise, it will block the pipes and flowrates will be changed
- The mixture should be chemically stable, safe and inexpensive.

Fig.1.1 presents the working principle of vapour-absorption refrigeration cycle.. As its name indicates, the vapour absorption refrigerator contains an absorber and a generator instead of a compressor (which is an integral part in vapour compression system). Different parts of a vapour absorption refrigerator are as follows:-

1. Evaporator
2. Absorber
3. Generator
4. Condenser

Water enters the evaporator at low temperature and pressure. Here water is in vapour –liquid state. This water refrigerant absorbs heat from the substance to be chilled and gets fully evaporated. As the boiling point of the refrigerant is high, process is being carried out in a low pressure or almost vacuum condition. This low pressure or vacuum condition helps in reducing the boiling point temperature of the refrigerant. A temperature around 3-4 ˚C can vaporise the water refrigerant. Then this water vapour enters the absorber section at constant pressure. Concentrated LiBr solution is present in absorber. Since water is highly soluble in LiBr solution, water vapour is absorbed through this concentrated solution making it dilute. At this point, it can be stated that, the power consumed by the compressor, is saved by this chemical absorption process which makes this system more energy saving and eco-friendly. From this absorber, dilute solution of LiBr+water is carried to the generator through a pump. Generator is the section where the refrigerant and absorbent are separated. Here heat is supplied to the solution. This heat is generally the waste heat coming out from data centres, steam power plants, hotels or big apartments. Water vaporises from the solution and moves to the condenser and the dilute LiBr+water solution becomes concentrated again and moves to the absorber. Condenser block is used as a device to condense the water vapour to liquid water. This can be done by passing normal cooling water or air flow. Generally a valve is used to reduce the pressure that is required in the evaporator.

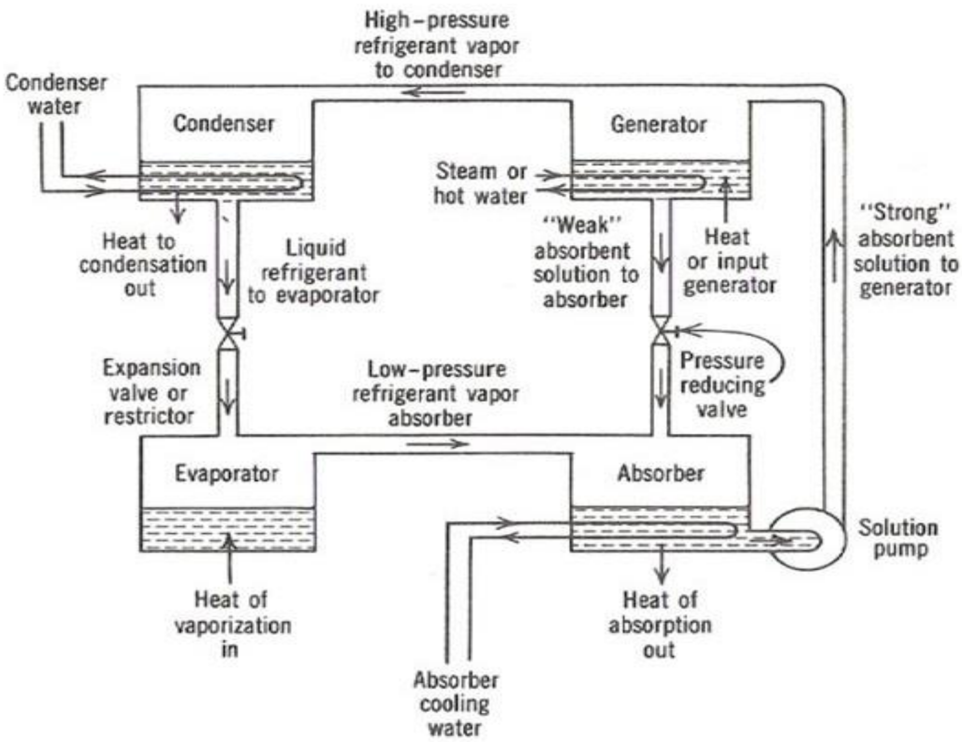


Fig:-1.1 vapour absorption refrigeration system [3]

1.4 OBJECTIVE AND SCOPE:-

Objective-

Recovery of low grade heat using absorption refrigeration system.

Scope-

1. Simulation, design and optimization of absorption refrigeration cycle using LiBr+water as working pair.
2. Techno-economic feasibility of absorption refrigeration system based on (LiBr + water) working pair.

1.5 CHAPTER LAYOUT –

- Chapter 1: This chapter contains Introduction to the absorption refrigeration system using LiBr + water as working pair.
- Chapter 2: This chapter describes about the theoretical postulations of absorption refrigeration cycle using LiBr + water as working pair.
- Chapter 3: This chapter presents simulation of absorption refrigeration cycle.
- Chapter 4: It presents the optimal design and economic feasibility of absorption refrigeration cycle.
- Chapter 5: The conclusions and future recommendation.

CHAPTER 2

THEORETICAL POSTULATIONS OF ABSORPTION REFRIGERATION CYCLE USING LiBr+WATER AS WORKING PAIR

ABSORPTION REFRIGERATION CYCLE –

Absorption refrigerator is a chemically driven refrigeration system which uses an absorbent-refrigerant combination as the main working pair. In case of LiBr+water combo, LiBr solution works as absorbent whereas water works as refrigerant. The basic features that make it convenient to use this combination as working pair is as follows [2]:-

- The refrigerant should be more volatile than the absorbent in other words the boiling point of refrigerant should me less than that of absorbent. This feature is easily followed by LiBr+water working pair.
- There should be large difference in their boiling points so that it will be easier to separate them in the generator. This ensures that pure refrigerant flows through the refrigerant circuit (condenser, expansion valve and evaporator). This property is also smoothly followed by this pair as LiBr solution has a much higher boiling point than the refrigerant water.
- The LiBr solution has a strong affinity for the refrigerant water.
- LiBr+water solution is cheap, environment-friendly and non-toxic.

The above features make this working pair more user friendly and eco-friendly to use in the absorption refrigeration cycle. But there are some limiting factors that need to have a close look while using this pair otherwise it will lead to a bigger problem [5]. These are as follows,

As working absorbent is an electrolyte solid in a solution form, higher concentration can lead to crystal formation which can block the pipes, hence it is needed to have a high pressure in the condenser and generator so that crystallization won’t happen at the working temperatures. Anti-crystallizers are being used to overcome this problem.[4]

- As the refrigerant used here is water hence it is needed to have a vacuum condition in the evaporator to decrease the boiling point of water. To maintain this vacuum condition is also a big challenge.
- Corrosion is another big problem. As water carries dissolved oxygen, this system is prone to metallic corrosion. This can be avoided by using anti-corrosive materials for the construction of this system.

Significance of vacuum condition can be found out from the boiling point reduction of refrigerant. Boiling point of water is a function of pressure. At atmospheric pressure, water boils at 100 ˚C. If pressure is lowered, then boiling point also decreases. The boiling point of water at 6mmHg comes down to 3.9 ˚C. Hence water can be easily evaporated with addition of less amount of heat.

2.1 WORKING PROCEDURE :-

Fig.2.1 presents the schematic of vapor-absorption refrigeration cycle. The cyclic process for the refrigerant loop is the same as that of a vapor compression system, except the mechanical compressor is replaced with a 'chemical compressor', which consists of an absorber, liquid pump, heat exchanger, desorber and expansion device. The pressurization process in the chemical compressor starts in the absorber, where the refrigerant vapor from the evaporator (state point 10) is exothermically absorbed into the weak (refrigerant) solution resulting in strong (refrigerant) solution to a state point 1. Once the refrigerant is absorbed, the working solution is pressurized by the liquid pump. The solution heat exchanger preheats the strong solution of state point 2 to state point 3 using the high temperature weak solution flow from the desorber. A high pressure and high temperature superheated refrigerant vapor is generated in the desorber and the refrigerant is endothermically desorbed from the strong solution. The refrigerant vapor returns to the refrigerant loop via condenser, expansion valve back to the evaporator. Meanwhile, the mixture solution becomes the weak solution and returns to the absorber through solution heat exchanger and expansion device in sequence, which completes the solution loop or chemical compression cycle. The most favourable working temperatures for a single effect LiBr+water absorption system are as follows [2]-

1. Generator Temperature, Tg= 55- 90 ℃
2. Condenser Temperature, Tc= 24- 46 ℃
3. Absorber Temperature, Ta = 16 -32 ℃
4. Evaporator Temperature, Te= 2.5- 10 ℃.

The operating temperatures chosen are as follows-

1. Generator Temperature, Tg =64℃
2. Condenser Temperature, Tc= 30℃
3. Absorber Temperature, Ta =20℃
4. Evaporator Temperature, Te =4℃

Operating pressures- The operating pressures can be known corresponding to the temperatures. For example, the saturation pressure for condensation is the condenser at 30 ˚C can be obtained from the steam table as 32 mmHg. As condenser and generator operate at same pressure, generator pressure is also same as 32 mmHg. Saturation pressure for saturated vapour formed in evaporator at 4 ˚C from steam table can be obtained as 6.1 mmHg which is same as the absorber temperature.

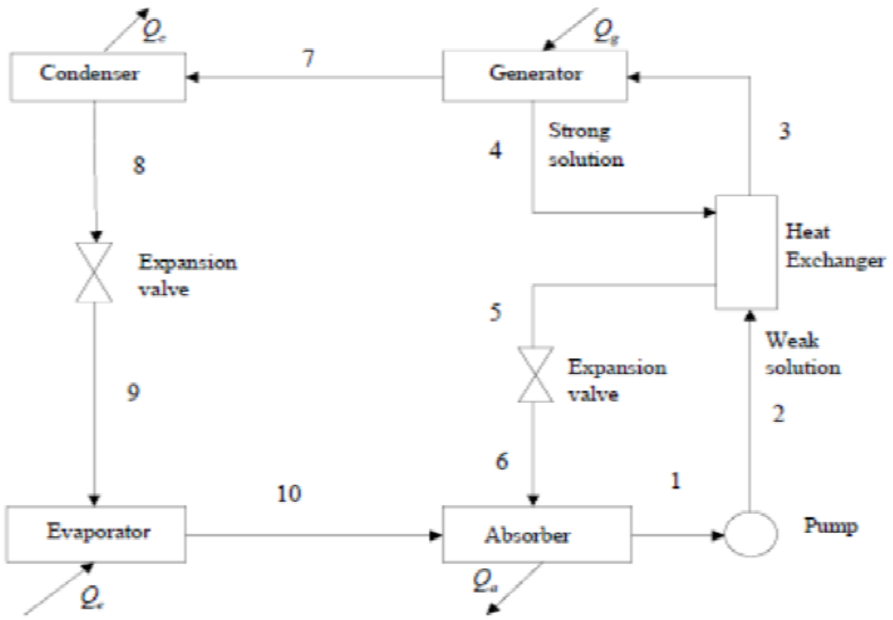


Fig:-2.1 vapour absorption refrigeration system [3]

- EVAPORATOR-

  Water enters the evaporator at low temperature and pressure. Here water is in vapour – liquid state. This water refrigerant absorbs heat from the substance to be chilled and gets fully evaporated. Then this water vapour enters the absorber section at constant pressure.
- ABSORBER-

  Concentrated LiBr solution is present in absorber. Since water is highly soluble in LiBr solution, water vapour is absorbed through this concentrated solution making it dilute.
- GENERATOR-

  Here heat is supplied to the solution. This heat is generally the waste heat. Water vaporises from the solution and moves to the condenser and the dilute LiBr+water solution becomes concentrated again and moves to the absorber
- CONDENSER-

  Condenser block is used as a device to condense the water vapour to liquid water. This can be done by passing normal cooling water or air flow. After condenser, a valve is places to decrease the pressure.

- HEAT-EXCHANGER-

  Normally a heat exchanger is used between generator and absorber so that heat can be exchanged between dilute solution and concentrated solutions.

- PUMP-

  Pump is used to move the dilute solution from absorber to the heat exchanger so that the required flow rate can be maintained.

Finding out enthalpy data:

Enthalpy of water and super-heated water can be found out from the steam tables at desired temperatures and pressures. Similarly, the enthalpy values can be found out at each point for the solution from the following T-P-h-X diagram presented in the Fig. 2.2 and tabulated in the Table 2.1 [2]

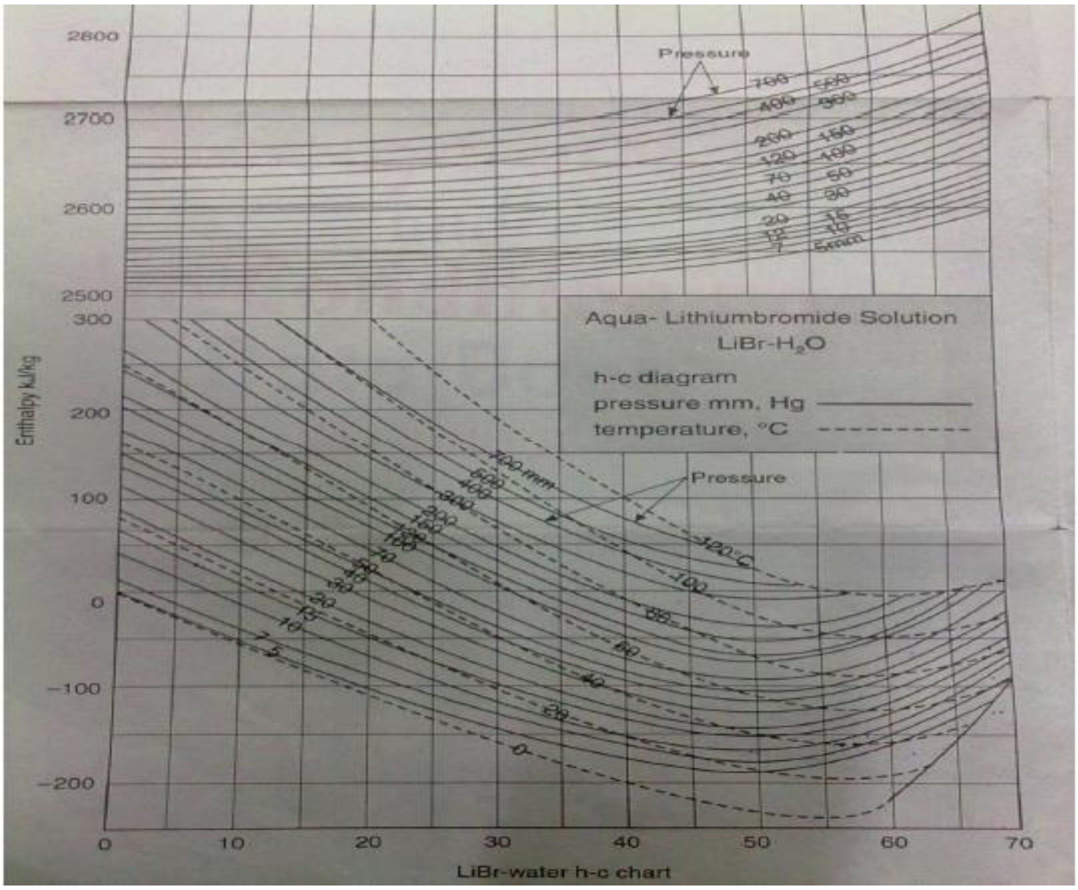


Fig. 2.2:- LiBr + Water T-P-h-x chart [2]

Table 2.1:- LiBr + water T-P-h-x data at different steams [2] [9]

State points	T (˚C)	P (mmHg)	h (KJ/Kg)	x
7	64	32	2616.5	0
8	30	32	125.7	0
9	30	6.1	125.7	0
10	4	6.1	2508.7	0
1	20	6.1	-180	.48
2	20	32	-180	.48
3	53.85	32	-115.7	.48
4	64	32	-120	.56
5	20	32	-195	.56
6	20	6.1	-195	.56

2.2 MASS AND ENERGY BALANCE :-

For condenser: - $m_7 - m_8 = m$ (2.1)

$$Q_C = mh_7 - mh_8 \tag{2.2}$$

For valve 1:- Isenthalpic Process

$$m_8 - m_9 = m \tag{2.3}$$

$$h_8 = h_9 \tag{2.4}$$

For evaporator:-

$$m_9 - m_{10} = m \tag{2.5}$$

$$Q_e = mh_{10} - mh_9 \tag{2.6}$$

For absorber :-$m + m_s = m_w$ (2.7)

$$Q_a = mh_{10} + mh_6 - m_w h_1 \tag{2.8}$$

For generator :- $m_3 = m_4 + m_7$ (2.9)

$$Q_g + m_w h_3 = h_7 m + m_s h_4 \tag{2.10}$$

$$\text{COP} = \frac{Q_e}{W_P + Q_d} = \text{m}\,(h_{10} - h_9) \div (\text{m}h_7 + m_s h_4 - m_w h_3 + W_P) \tag{2.11}$$

As W_p is negligible compared to Q_g, hence it is neglected.

Coefficient of Performance of an absorption refrigeration system is obtained as;

$$COP = \frac{cooling\ capacity\ obtained\ at\ evaporator}{Heat\ input\ to\ the\ generator + work\ input\ for\ the\ pump} = \frac{Q_e}{W_P + Q_d}$$

2.3 SAMPLE CASE STUDY :-

Using enthalpy values from Table 2.1, the energy balance can be done.

For evaporator ,

Qe = 5.25 KW = m (h10-h9) = m (2508.7 – 125.7)

Solving, the values of **m= 2.203 g/s**,

Circulation ratio f=Xw ÷ (Xs-Xw)

So **f =0.48/(0.56-0.48) = 6**

Therefore $\boldsymbol{m_s = f.m}$ **=13.22 g/s**

As we know $m_w = m_s$ + m , hence m_s= 15.42 g/s

For absorber applying the energy balance ,using equation (2.8),

Hence Qa =(2.203 × 2508.7)+(13.22 × -196) – (15.42× -180) = 5.724 KW

For generator , Qg = m.h7 + ms.h4 –mw.h3

So Qg = (2.203× 2616.5) +(13.22× -120) –(15.42 ×-115.7) = 5.906 KW

For condenser Qc = 2.203(2616.5 – 125.7) =5.487 KW

COP = Qe / Qg = 5.25 / 5.906 = 0.89 .

COP = 0.89

CHAPTER 3:-

SIMULATION OF ABSORPTION REFRIGERATION SYSTEM USING LiBr + WATER WORKING PAIR

The simulation of absorption refrigeration cycle can be done through various simulation software. The software chosen for this simulation work is ASPEN plus [6] [7]. Based on the simulation results of this chapter, an optimal design for this kind of absorption refrigeration system is expected to evolve. There are several steps to design a process flow-sheet for a successful simulation.

3.1 STATE POINTS AND ASSUMPTIONS –

TABLE 3.1 – Assumptions at state points for single effect absorption refrigeration cycle

State point	Assumption
1	Vapour quality ‘0’.
2	Determined by solution pump model
3	Determined by solution heat exchanger model
4	Saturated liquid
5	Determined by solution heat exchanger model
6	Determined by solution valve model
7	Saturated vapour
8	Vapour quality ‘0’
9	Determined by pump model
10	Vapour quality ‘1’

3.2 PROPERTY METHOD SELECTION-

The most important step in the modelling process is to find out a suitable property method for LiBr –water working pair. In this project ELECNRTL property method is being used, because the dissociation of LiBr in water forms electrolytic solution of lithium and bromide ions. Hence while inserting the components , electrolytic wizard is used.

3.3 SELECTION OF BLOCKS –

Fig. 3.1 presents the block diagram of LiBr + water absorption refrigeration cycle. Evaporator, condenser and absorber are done inserting heater block. As heating and cooling can be easily done by heater blocks, it is convenient to use heater blocks for these components. Flash drum is used as generator. Another heater block B10 is inserted before inlet to flash, so that the waste heat input can be provided to this block. Two valves are used to reduce the pressure in evaporator and absorber.

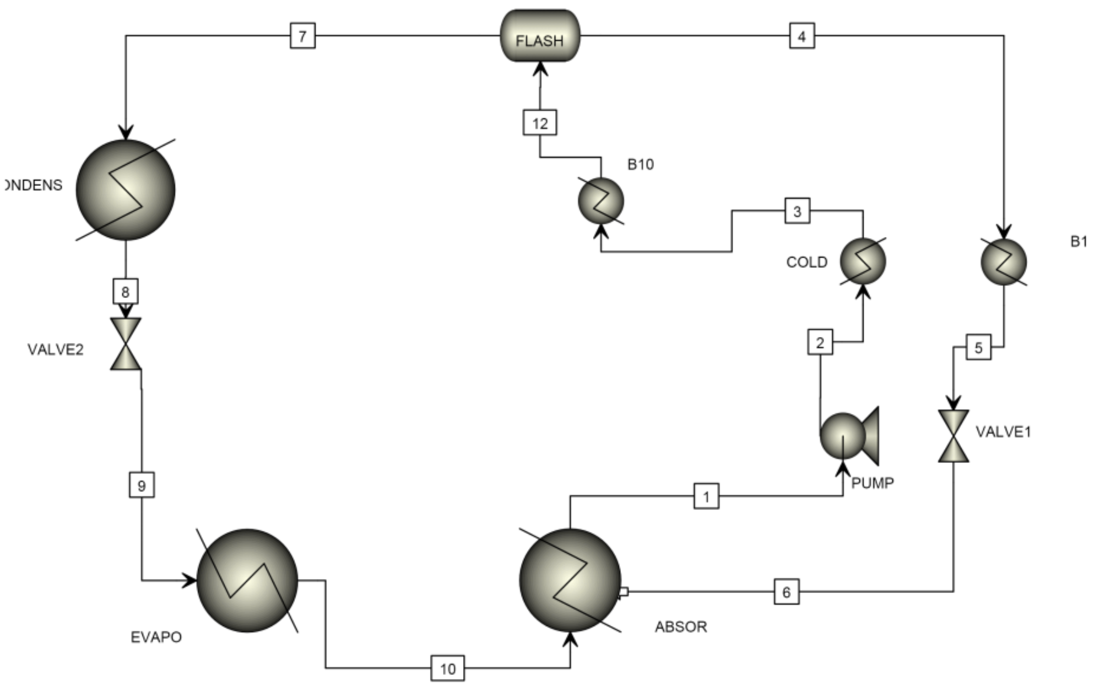


Fig – 3. 1 :- Block diagram of LiBr + water absorption refrigeration cycle

Temperature and pressure conditions for the simulation work

Absorber temperature = 20˚C

Evaporator temperature =4˚C

Condenser temperature =30˚C

Flash temperature = 64˚C

Absorber pressure = 6.1 mmHg

Evaporator pressure =6.1 mmHg

Condenser pressure =32 mmHg

Table 3. 1 evaporator condition

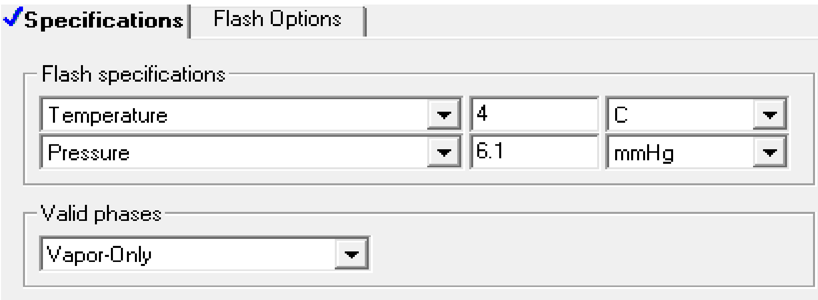


Table 3. 2 evaporator result

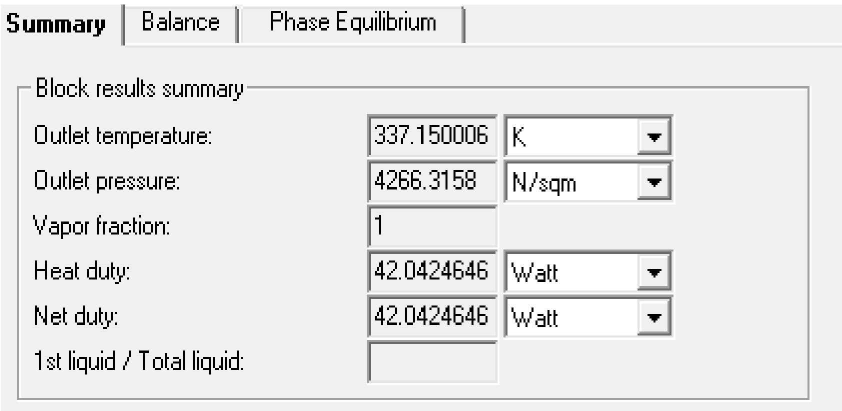
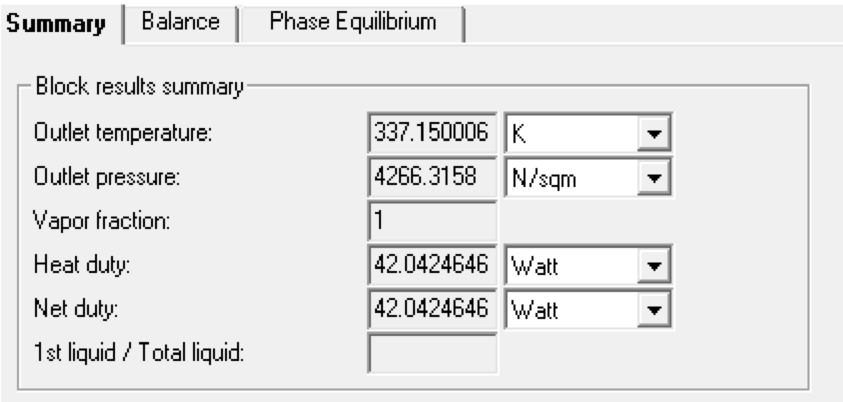


Table 3.3 flash conditions

Table 3. 4 flash result

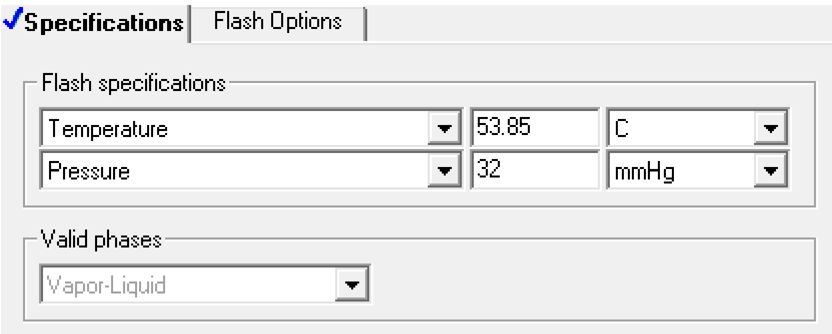


Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	337.150006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	42.0424646	Watt
Net duty:	42.0424646	Watt
1st liquid / Total liquid:		

Table 3. 5 B10 (external heat supplying block) conditions



✓Specifications | Flash Options

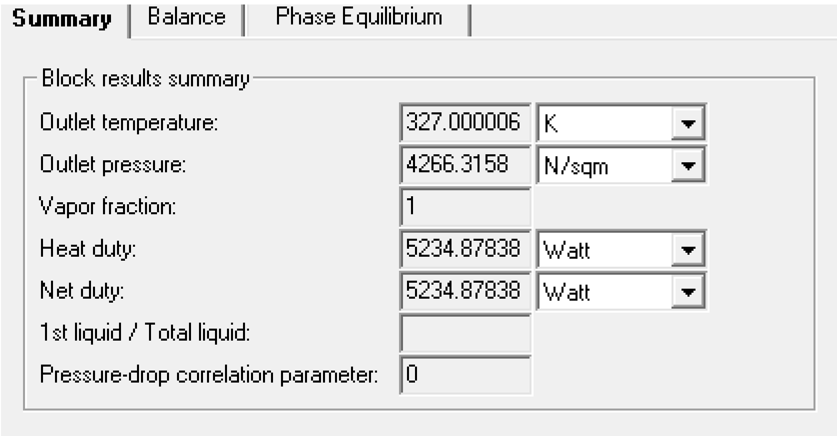
Flash specifications

Temperature	53.85	C
Pressure	32	mmHg

Valid phases

Vapor-Liquid

Table 3.6 B10 results



Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	327.000006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	5234.87838	Watt
Net duty:	5234.87838	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

Table 3. 7 Absorber conditions

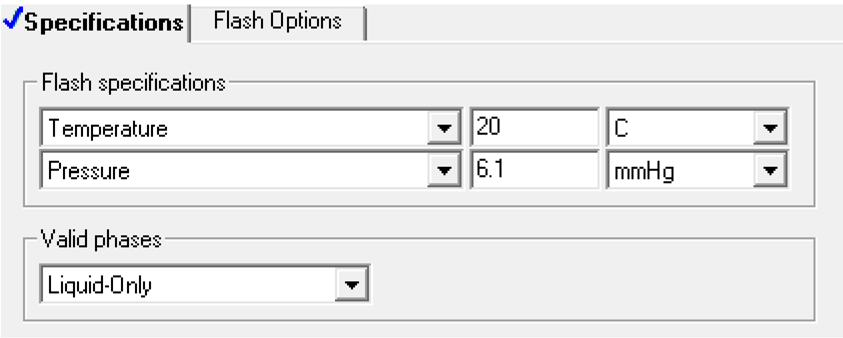


Table 3. 8 Absorber results

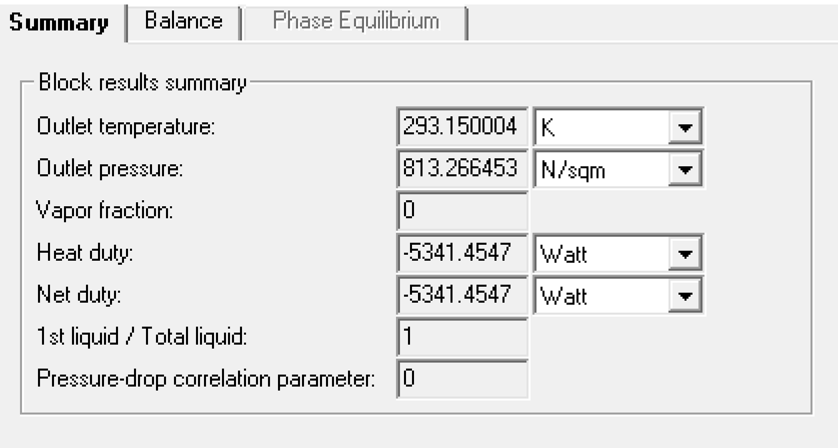


Table 3. 9 Condenser conditions

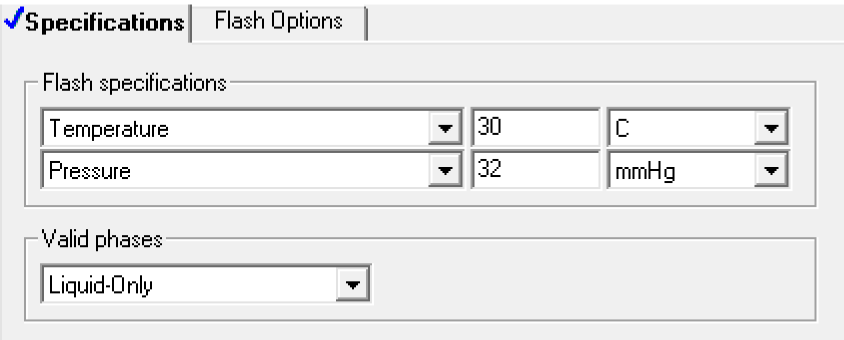


Table 3.10 Condenser result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	303.150005	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	0	
Heat duty:	-5496.5056	Watt
Net duty:	-5496.5056	Watt
1st liquid / Total liquid:	1	
Pressure-drop correlation parameter:	0	

3.4 COP CALCULATION-

COP can be calculated by dividing the heat duty of evaporator by the heat duty of generator. As the pump heat duty is negligible, it is not included in the calculation of COP.

Hence COP = Qe / Qg

Here Qe = heat duty of evaporator = 5249.38 W (from table 3. 2)

Qg = heat duty of flash block + heat duty of B10 block (from table 3. 4 and 3. 6)

For the sample simulation, COP can be calculated as follows-

Qg = 42.04 + 5234.88 =5276.92

COP = 5249.38 / 5276.92 = 0.994

CHAPTER 4 :-

OPTIMIZATION , DESIGNING AND ECONOMIC FEASIBILITY OF ABSORPTION REFRIGERATOR USING LiBr+WATER AS WORKING PAIR

4.1 OPTIMIZATION AND DESIGNING -

Optimum COP value can be found out from the set of values by changing one component temperature while keeping all other component temperatures as it is.[8]

First of all flash temperature is changed and corresponding COP values were calculated.

1. At flash temperature 90 ˚C

Table 4.1 evaporator result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	277.150004	K
Outlet pressure:	813.266453	N/sqm
Vapor fraction:	1	
Heat duty:	5249.38229	Watt
Net duty:	5249.38229	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

Table 4.2 B10 result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	327.000006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	5234.87838	Watt
Net duty:	5234.87838	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

Table 4. 3 flash result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	363.150007	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	150.104511	Watt
Net duty:	150.104511	Watt
1st liquid / Total liquid:		

2. At flash temperature 70 ˚C

Table 4.4 evaporator result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	277.150004	K
Outlet pressure:	813.266453	N/sqm
Vapor fraction:	1	
Heat duty:	6925.36592	Watt
Net duty:	6925.36592	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

Table 4.5 flash result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	343.150007	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	88.3014547	Watt
Net duty:	88.3014547	Watt
1st liquid / Total liquid:		

Table 4.6 B10 result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	327.000006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	6906.23134	Watt
Net duty:	6906.23134	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

3. At flash temperature 80 ˚C

Table 4.7flash result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	353.150007	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	106.275006	Watt
Net duty:	106.275006	Watt
1st liquid / Total liquid:		

Table 4.8 evaporator result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	277.150004	K
Outlet pressure:	813.266453	N/sqm
Vapor fraction:	1	
Heat duty:	5249.38229	Watt
Net duty:	5249.38229	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

Table Fig 4.9 B10 result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	327.000006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	5234.87838	Watt
Net duty:	5234.87838	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

4. At flash temperature 60 ˚C

Table 4.10evaporator result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	277.150004	K
Outlet pressure:	813.266453	N/sqm
Vapor fraction:	1	
Heat duty:	3977.32441	Watt
Net duty:	3977.32441	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

Table 4.11 flash result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	333.150006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	19.2940423	Watt
Net duty:	19.2940423	Watt
1st liquid / Total liquid:		

Table 4.12 B10 result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	327.000006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	3966.33518	Watt
Net duty:	3966.33518	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

5. At flash temperature 58 ˚C

Table 4.13 evaporator result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	277.150004	K
Outlet pressure:	813.266453	N/sqm
Vapor fraction:	1	
Heat duty:	3225.82488	Watt
Net duty:	3225.82488	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

Table 4.14 flash result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	331.150006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	10.5576742	Watt
Net duty:	10.5576742	Watt
1st liquid / Total liquid:		

Table 4.15 B10 result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	327.000006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	3216.91203	Watt
Net duty:	3216.91203	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

6. At flash temperature 55 ˚C

Table 4.16 evaporator result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	277.150004	K
Outlet pressure:	813.266453	N/sqm
Vapor fraction:	1	
Heat duty:	5249.38229	Watt
Net duty:	5249.38229	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

Table 4.17 flash result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	328.150006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	4.75959179	Watt
Net duty:	4.75959179	Watt
1st liquid / Total liquid:		

Table 4.18 B10 result

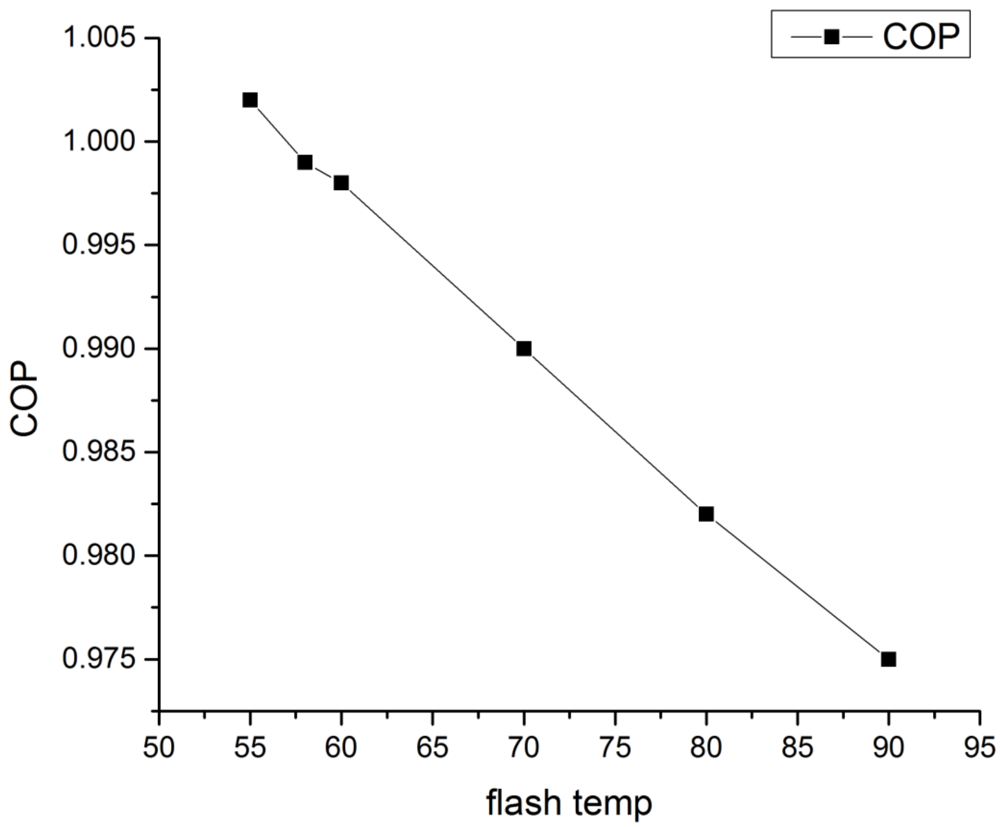
Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	327.000006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	5234.87838	Watt
Net duty:	5234.87838	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

Table - 4.19 temperature of flash vs COP

Temperature(˚C)	COP
90	0.975
80	0.982
70	0.990
60	0.998
58	0.999
55	1.002

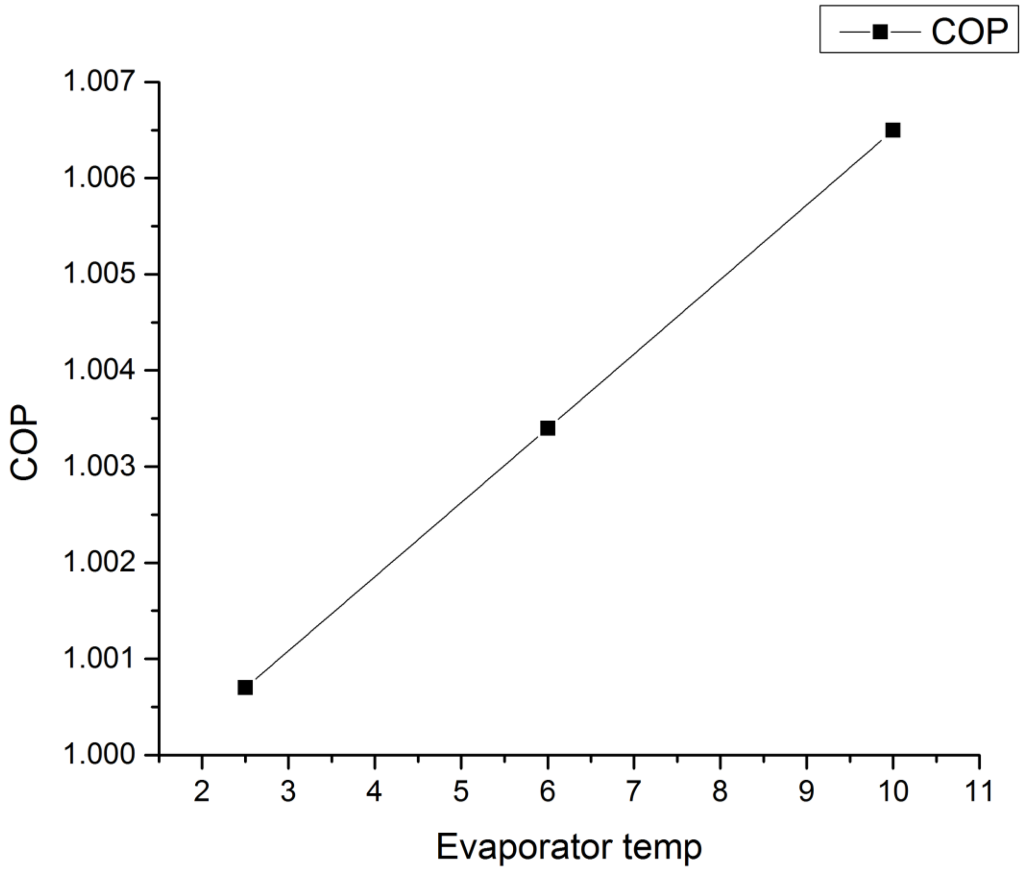


Graph 4.1 flash temperature(˚C) vs COP

Maintaining the flash temperature at 55 ˚C evaporator temperature is changed and subsequently COP value is calculated.

Table 4.20 evaporator temperature vs COP value

Temperature(˚C)	COP
2.5	1.0007
6	1.0034
10	1.0065



Graph 4.2 evaporator temperature (˚C) vs COP

4.1 OPTIMUM CONDITION

Optimum condition of temperature of different blocks are from the chapter 3:-

- Evaporator temperature = 10 ˚C
- Absorber temperature = 20 ˚C
- Condenser temperature =30 ˚C
- Flash temperature =55 ˚C

Table 4.21 condenser result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	303.150005	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	0	
Heat duty:	-5459.2227	Watt
Net duty:	-5459.2227	Watt
1st liquid / Total liquid:	1	
Pressure-drop correlation parameter:	0	

Table 4.22 evaporator result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	283.150004	K
Outlet pressure:	813.266453	N/sqm
Vapor fraction:	1	
Heat duty:	5274.01899	Watt
Net duty:	5274.01899	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

Table 4.23 absorber result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	293.150004	K
Outlet pressure:	813.266453	N/sqm
Vapor fraction:	0	
Heat duty:	-5366.0914	Watt
Net duty:	-5366.0914	Watt
1st liquid / Total liquid:	1	
Pressure-drop correlation parameter:	0	

Table 4.24 flash result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	328.150006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	4.75959179	Watt
Net duty:	4.75959179	Watt
1st liquid / Total liquid:		

Table 4.25 B10 result

Summary | Balance | Phase Equilibrium

Block results summary

Outlet temperature:	327.000006	K
Outlet pressure:	4266.3158	N/sqm
Vapor fraction:	1	
Heat duty:	5234.87838	Watt
Net duty:	5234.87838	Watt
1st liquid / Total liquid:		
Pressure-drop correlation parameter:	0	

Table 4.26   Optimum heat duty

Component	Heat duty(w)
Evaporator	5274.02
Flash	0004.76
B10	5234.88
Absorber	-5366.09
Condenser	-5459.22
Pump	0.00762

Optimum COP = 5274.02/ (4.76 + 5234.88) = 1.0065

4.2 ECONOMIC ESTIMATION –

Basis – let a plant works for 8 hr a day for 300 days in a year. In general, electricity consumption cost is Rs 6.90/- per KWh.

Total fixed cost of a 1.5 ton absorption refrigeration system using LiBr- water is = $ 5000 /-

When it is converted to Rupees. its fixed cost is = Rs 5000×60= 3,00,000/-

The average lifetime of this refrigerator is 10 yrs.

Hence annual fixed cost is = Rs 30,000/yr

Operating cost can be found out as follows-

Heat duty of evaporator = 5.274 KW

Per yr heat duty= 5.274× 8× 300 =12657.6 KWh

Per yr generator heat duty = 5.239× 8× 300 =12573.6 KWh

Per yr absorber heat duty = 5.366× 8× 300 = 12878.4 KWh

Per yr condenser heat duty = 5.459× 8× 300 = 13,101.6 KWh

Per yr pump heat duty = 0.00762× 8× 300 = 18.288 KWh

Per yr heat duty for two pumps = 36.576 KWh

Total annual heat duty = 51247.776 KWh

Total annual cost = 51247.776 KWh×6.9 = 3,53,609.65 /-

Market cost of 55% LiBr solution = Rs 3,24,000 /- per 1000 kg.

Total cost of LiBr+water absorption refrigeration system = 3,53,609.65 + 30,000 = 3,83,609.65/-

4.3 COMPARISION WITH VAPOR COMPRESSION REFRIGERATOR -

Fixed cost of a 1.5 ton vapour compression refrigerator = Rs 40,000/-

Its average life time is 1 to 4 yrs. for industrial purpose. Taking life time for 2 yrs., annual fixed cost = Rs 20,000/-

Heat duty of 1.5 ton vapour compression refrigerator = 1.2 KW

For 8 hr of operation, annual heat duty = $1.2 \times 8 \times 300 = 2880$ KWh

This operating cost = 2880×6.9 = Rs 19872/-

Total cost = fixed cost + operating cost = Rs 39,872/-

Cost of 1.5 ton vapour absorption refrigeration cycle using LiBr+water as working pair = Rs 30,000/- per yr

Extra heat duty needed for operation = heat duty of absorber – heat duty of generator = 12,878.4- 12,573.6 = 304.8 KWh

Cost of this heat duty = 304.8×6.9 = Rs 2103.12/-

Total cost = fixed cost + pump cost + extra heat duty cost

= 30,000+ 36.576×6.9 + 2103.12 = Rs 32,355 /-

Gross profit of absorption refrigeration cycle using LiBr water as working pair over conventional vapour compression cycle = 39,872 – 32,355 = Rs 7,517/-

CHAPTER 5

CONCLUSIONS AND FUTURE RECOMMENDATIONS

5.1 CONCLUSIONS –

For successful completion of this work, caution has been taken while doing the flow sheet construction and property method selection. From this project, it can be concluded that COP of the system is dependent on the evaporator and generator temperature. With suitable adjustment of the temperatures in these blocks can optimize the COP value and this can be seen from the chapter 4. It can be found out that, the COP of LiBr + water based absorption refrigeration system is higher than that of ammonia + water based system. There are some demerits in this system like the crystallization, corrosion and leakage problems which need to be given serious consideration, because they can pose limitation on operating conditions of this system, hence limiting the COP of the cycle. Recently, ionic liquid + water based absorption refrigeration system has been proposed, which is much costlier than the LiBr + water based system. In this project, economic feasibility has also been checked by taking a simple basis. When compared with the conventional vapour compression refrigeration system, it can be visualized that, the LiBr+water system has an annual average profit of around Rs. 7500/- which is the clear indication of economic profitability of this system. Moreover, the LiBr + water system doesn't harm the environment and uses the waste heat which could otherwise affect the nature.

5.2 FUTURE RECOMMENDATIONS –

The simulation studies have been done in a very simple way of choosing heater blocks for most of the components. As COP calculation is our main purpose, this selection is fine, but if detailed designing is needed, then other blocks like heatx etc. can be used. There is a much required work needed for the improvement in crystallization property either by inclusion of other salts or by using anti-crystallizers, though it was not included in the scope of the present project . Hence the future scope lies in the improvement of anti-crystallinity property. Other thermodynamic properties can also be found out like mass transfer coefficient, mass flux, heat flux, heat transfer and effectiveness of each component. A detailed comparative study can be done taking LiBr+water, ammonia-water and ionic liquid + water , so that economic feasibility can be easily determined.

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